LIFAC SORBENT INJECTION : AN ALTERNATIVE SO_2 CONTROL STRATEGY

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Introduction

The Clean Coal Technology Program (CCT) has been recognized in the National Energy Strategy as a major initiative whereby coal will be able to reach its full potential as a source of energy for the nation and the international marketplace. Attainment of this goal depends upon the development of highly efficient, environmentally sound, competitive coal utilization technologies responsive to diverse energy markets and varied consumer needs. The CCT Program is an effort jointly funded by government and industry whereby the most promising of the advanced coal-based technologies are being moved into the marketplace through demonstration. The CCT Program is being implemented through a total of five competitive solicitations. This paper discusses the LIFAC sorbent injection technology which was selected in the third round of CCT solicitations.

LIFAC North America, a joint venture partnership of ICF Kaiser Engineers, Inc. and Tampella Power Corporation of Finland, will demonstrate the LIFAC flue gas desulfurization technology developed by Tampella. This technology provides sulfur dioxide emission control for powerplants, especially existing facilities with tight space limitations. Sulfur dioxide emissions are expected to be reduced by up to 85% by using limestone as a sorbent. The limestone is injected into the upper regions of a furnace, where calcining to lime and partial absorption of SO_2 occur. Subsequently, the combustion gas is passed through a unique piece of equipment known as the activation reactor. This is a vertical elongation of the ductwork between the air preheater and ESP where the combustion gas is humidified and SO_2 absorption is completed. The LIFAC technology will be demonstrated at Whitewater Valley Unit No. 2, a 60-MWe coal-fired powerplant owned and operated by Richmond Power and Light (RP&L) and located in Richmond, Indiana. The Whitewater plant consumes high-sulfur coals with sulfur contents ranging from 2.0 - 2.9 percent.

The project, co-funded by LIFAC North America and DOE, is being conducted with the participation of Richmond Power and Light, the State of Indiana, the Electric Power Research Institute, and the Black Beauty Coal Company. The project has a total cost of 21.4 million dollars and a duration of 48 months from the preliminary design phase through the testing program.

The sponsors of this project believe that LIFAC has the potential to be a new and important SO_2 control option for U.S. utilities subject to the Clean Air Act's acid rain regulations. To be considered as a commercially feasible option in this particular emissions control market, LIFAC must demonstrate a high SO_2 removal rate while remaining competitive with other options on a cost per ton of SO_2 removed basis. To this end, the sponsors of this project have designed the demonstration with the following goals in mind:

- Sustained High SO_2 Removal Rate - Incorporated into the test plan are several periods of long term testing which are intended to demonstrate LIFAC's SO_2 removal and reliability characteristics under normal operating conditions.

- Cost - LIFAC must compete with both low capital cost, low SO_2 removal rate options such as sorbent injection and high capital cost, high SO_2 removal rate options such as wet scrubbing. This project will demonstrate LIFAC's competitiveness on a cost per ton of SO_2 removed basis with these currently available alternatives.

- Retrofit Adaptability - The host site chosen required a retrofit with tight construction conditions that will prove LIFAC's ability to be installed where other technologies might not be possible. Construction was also to demonstrate LIFAC's ability to be built and brought on-line with zero plant down time other than scheduled outages.

- System Compatibility - A major concern of utilities is the degree of compatibility of SO_2 removal systems with their existing operations. This demonstration will show LIFAC's minimal impact on the host site's boiler and associated subsystems.

LIFAC Process History and Description
In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization systems have the capability to remove about 80 percent of the sulfur dioxide in the flue gas. Tampella Power, therefore, began developing an alternative, economical sorbent injection system. Initially, development first involved laboratory and pilot plant tests, then full-scale tests of sorbent injection of limestone. Subsequent research and development by Tampella led to the addition of a humidification section after the furnace which became known as the LIFAC process.

In 1986, the first large full scale test was performed at Imatran Voima's Inkoo powerplant using a 70 megawatt side-stream from a 250 megawatt boiler. A 76 percent SO_2 removal rate with 1.5% sulfur coal was reached. A second LIFAC activation reactor was constructed to handle an additional 125 megawatt side-stream. This newer reactor is achieving removal rates of 75 to 80 percent while using Ca/S molar ratios of between 2 and 2.5 to 1. Also, in 1988 the first tests with high-sulfur U.S. coals were run at the Neste Kulloo Laboratory. A Pittsburgh No. 8 Seam coal containing 3 percent sulfur was tested and an SO_2 removal rate of 77 percent was achieved at a Ca/S molar ratio of 2 to 1.

LIFAC Process Description
The LIFAC system combines conventional limestone injection into the upper furnace region with a post-furnace humidification reactor located between the air preheater and the ESP. The process produces a dry, stable waste product that is removed from both the bottom of the bumidification reactor and the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper region of the boiler where temperatures are approximately 1800 to 2200 degrees Fahrenheit. At these temperatures the limestone ($CaCO_3$) calcines to form lime (CaO) which readily reacts with the SO_2 to form calcium sulfate ($CaSO_4$). All of the sulfur trioxide (SO_3) reacts with the CaO to form $CaSO_4$.

Approximately 25 percent of the sulfur dioxide removal occurs in the boiler with the remaining 75 percent and the unreacted lime passing through the air preheater to the humidification reactor. There the flue gas is sprayed with water that allows the unreacted lime to hydrate to $Ca(OH)_2$ which more readily reacts with the sulfur dioxide and forms $CaSO_3$. A combination of the proper water droplet size and residence time allows for effective hydration of the lime and complete water evaporation to create a dry reactor bottom product.

After exiting the humidification reactor, the flue gas is reheated before entering the ESP. The humidification and lower gas temperature enhance the efficiency of the ESP. Seventy-five percent of the LIFAC-produced spent sorbent and fly ash is collected by the ESP with the other 25 percent collected by the humidification reactor. Both the reactor and ESP ash may be recycled to a point ahead of the reactor to improve sorbent utilization and to improve the SO_2 removal efficiency of the system to the range of 75 to 85 percent. A schematic of the LIFAC process is shown in Figure 1 along with the typical sampling locations used during the demonstration.

Process Advantages
LIFAC is similar to other current sorbent injection technologies but has unique advantages with its use of a patented vertical humidification reactor. And while LIFAC's sulfur dioxide removal efficiency is not as high as traditional wet flue gas desulfurization systems, its cost and simplicity of design, construction and operation offer other advantages over these alternative systems. In particular the advantages of the LIFAC system are:

- High SO_2 removal rates - Currently available sorbent injection systems have been unable to sustain high SO_2 removal rates with any consistency. LIFAC has proven in the past and intends to demonstrate during this project the ability to achieve and sustain high SO_2 removal rates of 75 to 85 percent over long operating periods.

- By-products - Wet lime and limestone scrubbing systems create a wet byproduct ash that must be further treated before disposal. LIFAC produces a dry solid waste ash containing calcium sulfide, calcium sulfate and fly ash. This waste is easily disposed of under U.S. regulatory requirements, may be recycled to increase LIFAC's efficiency and may have commercial applications in the cement industry.

- Compatibility and Adaptability - LIFAC has minimal impact on the host's site and systems, primarily the boiler, ESP and ID fan. In addition, LIFAC requires little space and few utilities and therefore is easily installed even in small or cramped powerplant sites.

Construction and Systems Integration
Construction of the LIFAC system has occurred in two phases over a period of one and a half years. The first phase of construction was completed during a routine plant outage in March, 1991. The period was utilized to install tie-ins to the host site's existing systems.

Ductwork and three dampers were installed between the air preheater and ESP to allow flue gas flow to the LIFAC activation reactor. Tie-ins were also made to the powerplant's high-pressure steam, condensate and river-water supplies. The high-pressure steam is required to reheat the flue gas exiting the LIFAC reactor and the water is needed for flue gas humidification inside the reactor. Injection ports were also installed in the boiler walls about 10 feet above the nose elevation.

The second phase of construction began in the Fall of 1991 with the driving of reactor piling and the installation of underground conduit runs. Work continued through to the Summer of 1992 with no need for plant downtime other than normally scheduled outages. During this time the limestone storage area was completed and the injection system was installed on Unit #2. The activation reactor was constructed and then tested with both cold air during a scheduled Unit #2 outage and hot flue gas during a low electricity demand period. Other powerplant tie-ins such as the steam and condensate system were also tested during low demand periods in the evening or on weekends.

Schedule
The current schedule for the LIFAC demonstration program extends over a four year period from the beginning of preliminary design in August 1990 through the testing program to be completed in early August 1994. However, preliminary test results are now available.

Currently the demonstration project is on schedule. All construction work was completed at the beginning of August 1992. Equipment check-out was performed in July and August and the first limestone delivery was received in early September. Initial tests with limestone injection into the boiler along with post-furnace humidification were conducted in October to December 1992. The project team was prepared to conduct the test plan beginning in early 1993.

Test Plan
The test plan for the LIFAC demonstration is composed of five distinct phases, each with its own objective. The first of these phases, which has already been completed, consisted of the initial baseline testing portion of the project. Measurements were taken to characterize the operation of the host's boiler and associated subsystems prior to the use of the LIFAC system.

The second, or parametric, phase of testing is currently underway and will be performed to determine the best combination of LIFAC process variables for SO_2 removal. The variables being studied include the limestone injection nozzles' angle and location, the Ca/S molar ratio, the need for supplemental injection air at the boiler, the water droplet size and injection nozzle arrangement in the reactor, the ash recycling ratio and the approach to saturation temperature of the flue gas exiting the activation reactor. The best combination of these variables will be chosen at the conclusion of this phase and used for the remainder of the test program.

Optimization tests will be conducted to examine the effects of different coal and limestone feeds on the SO_2 capture rate. Coals with sulfur contents as high as 3.3 percent will be tested to determine LIFAC's compatibility with high sulfur U.S. coals. Limestones with different compositions will also be tested to determine the LIFAC system's adaptability to local sorbent sources.

Long term testing will also be performed to demonstrate LIFAC's performance under commercial conditions. The LIFAC system will be in operation 24 hours per day for several weeks using the powerplant's baseline coal, high calcium limestone and the optimum combination of process variables.

The final phase of testing is composed of the post-LIFAC tests. The baseline tests will be repeated to gather information on the condition of the boiler and its associated subsystems. Comparisons will be made to the original baseline data to identify any changes either caused by the LIFAC system or independent of its operation.

Preliminary Results

Parametric testing was initiated at 60 MW to assess the broad impacts of limestone injection, flue gas humidification, and sorbent recycle. Figure 1 shows average reductions achieved throughout the LIFAC process. About 22 percent SO_2 reduction is achieved in the boiler. This is increased to about 52 percent with humidification, and further raised to 75 percent with the use of sorbent recycle from the ESP ash hoppers. These tests were conducted with a fine grind limestone (80% minus 325 mesh) with a Ca content above 90 percent. A Ca/S molar ratio of 2.0 was held near constant and a 4 to 5^{o} Fahrenheit approach to saturation was maintained in the activation reactor.

Figure 2 shows the impacts of varying the Ca/S molar ratio. The majority of the tests have been conducted at 2.0, but the trends are as expected. The higher the Ca/S ratio, the higher the SO_2 reduction. Results show, however, that SO_2 reductions of 75 to 85 percent are possible when spent sorbent is recycled and a 3 to 5^{o} Fahrenheit approach to saturation temperature is maintained.

Figure 3 shows the impact of recycling spent sorbent under various boiler loads. The Ca/S molar ratio was maintained at about 2.0 and the level of humidification is high (4 to 5^{o} Fahrenheit above saturation). Generally, there is an 18 to 25 percentage point increase in SO_2 reduction as a result of sorbent recycle. With recycle, total SO_2 reductions ranged from 75 to 85 percent depending on boiler load.

At this point it has been shown at RP&L and other LIFAC installations that the system can be installed and operated without affecting normal powerplant operations. It will also be shown that the system can economically reduce SO_2 emissions when compared with other flue gas desulfurization technologies.

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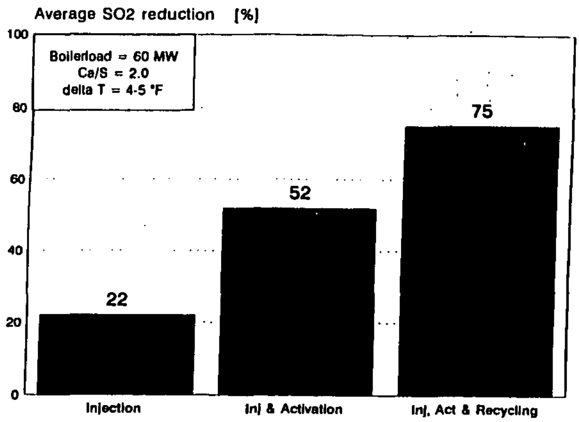

Figure 1. PARAMETRIC EFFECTS

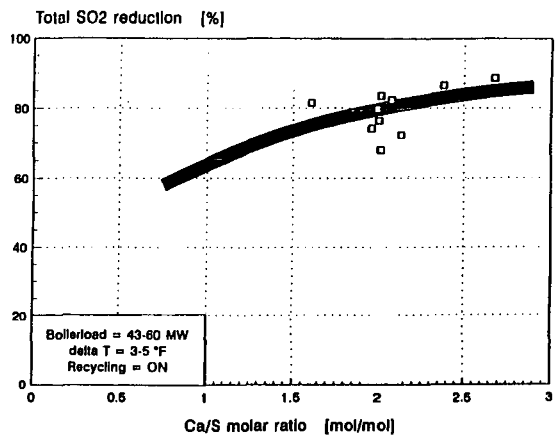

Figure 2. SO_2 REDUCTION vs. Ca/S MOLAR RATIO

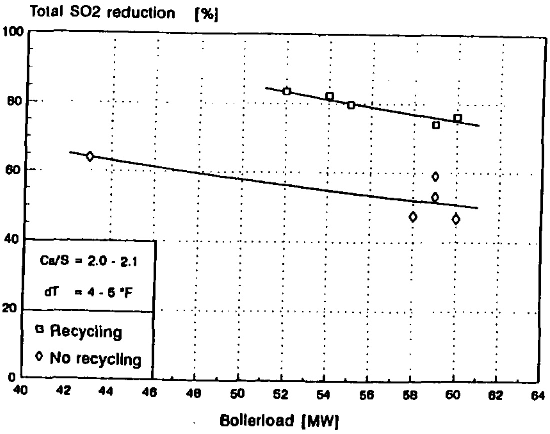

Figure 3. SO_2 REDUCTION vs. BOILER LOAD